Fully-funded 4 year PhD studentship

Constraints on palaeohydrology of Lower Strength Sedimentary Rocks (LSSR) using a novel analytical toolkit

Lower Strength Sedimentary Rocks are a high priority for characterisation for the UK's development of potential geological disposal facilities. These include the Mercia Mudstone Group (MMG), a package of mud-rich sedimentary rocks that outcrops across a large region of the UK, and forms one of the key sedimentary units identified as a potential target lithology for nuclear waste storage. Determining a history of past fluid-flow can better inform us about current and potential future fluid migration and pathways that fluids will take, and as such forms a key part of the characterisation involved in the safety assessment and management of nuclear waste disposal. Fluid-flow events can leave fingerprints such as veins and cements, and these can be measured with a variety of analytical tools to quantify both the timing of fluid-flow and source of the fluids. These fluid-flow fingerprints form the subject of this PhD.

Traditional methods of determining past fluid-flow events, i.e. palaeohydrology, have relied on the presence of fluid inclusions, as well as stable carbon and oxygen isotopes, and radiogenic strontium isotopes; all of which are applied to quartz and carbonate mineralisation. Recently developed techniques now include carbon, oxygen and sulphur isotope measurements with high spatial resolution using micro-milling and/or ion-microprobe measurement, *in situ* U-Pb geochronology of carbonates, and clumped carbon isotope measurements for thermometry. Ongoing developments in mass spectrometry allow an even broader range of both stable and radiogenic isotope compositions to be measured in various mineral phases, including U and Sr isotopes, and U-Th, Rb-Sr and Lu-Hf geochronology. Using laser ablation for *in situ* sampling provides high spatial resolution analysis, allowing targeting of veins and cements at the <100 μm scale.

This PhD project will use state-of-the-art laboratories at the British Geological Survey (BGS, Keyworth) to apply both traditional and novel isotope geochemical methods to mineral veins and cements within several LSSR units, including the Mercia Mudstone Group. The key analytical objectives of this project are to: 1) develop geochronological tools to determine the timing of cement and vein formation of carbonates (e.g. calcite, dolomite) and sulphates (e.g. gypsum), and 2) develop analytical tools to isotopically fingerprint fluid-sources of carbonate and sulphate mineralisation. The completion of both objectives will entail a combination of 1) fieldwork, petrography and fluid-inclusion measurements; 2) isotope measurements including carbon, oxygen, sulphur, strontium and uranium isotopes, measured with high spatial resolution using micro-milling or laser ablation- based methods; and 3) geochronology involving all or some of the following: U-Pb, U-Th, Rb-Sr and Lu-Hf dating of carbonates and sulphates (Fig. 1). These methods will be applied to both outcropping and subcropping (through core material) regions of the MMG and other LSSR units such as the Sherwood Sandstone. These regions will be chosen to cover both tectonically complex regions, such as in SW England within the Variscan foreland, as well as regions outside of the Variscan Front with less tectonic complexity, such as the East Midlands. The aim of sampling these regions, even if they are not suitable locations for a GDF, is to constrain how deformation events (e.g. folding and faulting) influence fluid migration, and to compare these with sedimentary units that have undergone a simpler history of burial and uplift. There is some flexibility in the analytical programme to allow the student to develop the most efficient and

robust toolkit that constrains the palaeohydrological history recorded within the vein mineralisation.

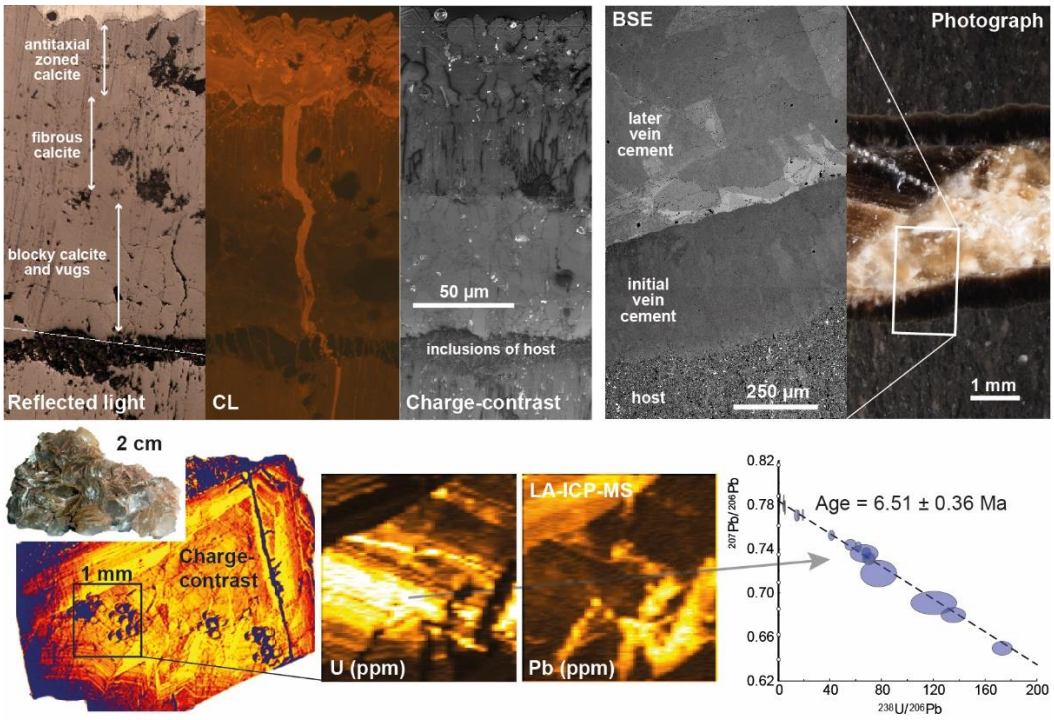

Fig. 1 Example of elemental maps made using LA-ICP-MS proposed for this project. This highlights the strength of in situ measurements for dating and fingerprinting fluid flow events. Figure from Roberts et al., 2020

The data generated during this PhD will provide a comprehensive history of past fluid-flow events that have affected fluid migration and permeability conditions of the MMG within specific target areas. This will better inform about the potential migration pathways ongoing and in the future. The development and proving of a novel and robust analytical toolkit will demonstrate the modern analytical capabilities that academic and industrial communities within the UK can apply to other societally relevant rock volumes to understand fluid-flow histories, such as those useful for sub-surface storage (e.g. CCS).

Funding:
Nuclear Waste Services fully funded studentship for 4 years, stipend of £17,668/ year, full home fees paid and a research grant to cover analytical, fieldwork and other research costs.

Host Institutions and supervisors:
Jointly supervised by Dr. Catriona Menzies (University of Durham) and Dr Nick Roberts (BGS Keyworth), PhD will be awarded from Durham University with the majority of laboratory work and training undertaken at BGS Keyworth.

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Further Reading:
Nick M.W. Roberts, Richard J. Walker, 2016 U-Pb geochronology of calcite-mineralized faults: Absolute timing of rift-related fault events on the northeast Atlantic margin. Geology; 44 (7): 531–534. doi: https://doi.org/10.1130/G37868.1

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Roberts, N. M. W., Drost, K., Horstwood, M. S. A., Condon, D. J., Chew, D., Drake, H., Milodowski, A. E., McLean, N. M., Smye, A. J., Walker, R. J., Haslam, R., Hodson, K., Imber, J., Beaudoin, N., and Lee, J. K. 2020: Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U–Pb carbonate geochronology: strategies, progress, and limitations, Geochronology, 2, 33–61, https://doi.org/10.5194/gchron-2-33-2020 , 2020.